Open-field Behavior in Rats Exposed Prenatally to a Low Intensity-Low Frequency, Rotating Magnetic Field

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PERSINGER, MICHAEL A., (1969). *Open Field Behavior in Rats Exposed Prenatally to a Low Intensity-Low Frequency, Rotating Magnetic Field.* DEVELOPMENTAL PSYCHOBIOLOGY, 2(3): 168–171. Two experiments were conducted to study the behavioral effects of prenatal exposure to a low intensity, ultra-low-frequency magnetic field. In Experiment 1, 117 albino rats that had been exposed continuously during their prenatal development to a 3 to 30 gauss, 0.5 Hz rotating magnetic field (RMF), and 83 control rats that had been exposed prenatally to control conditions, were tested in an open field at 21 to 25 days of age. RMF-exposed animals traversed significantly fewer squares than their controls in the open field ($p < .001$), but defecated significantly more in that situation ($p < .001$). RMF-exposed males also traversed significantly fewer squares than the RMF-exposed females ($p < .05$). Three RMF-exposed litters that were nursed by control mothers did not differ significantly in open-field activity from the pups in the 4 RMF-exposed litters from which they were taken at birth. In Experiment 2, in which the experimenters did not know whether the subject was a RMF-exposed rat or a control rat, 19 RMF-exposed rats again traversed significantly fewer squares than the 20 control rats ($p < .01$).

open-field behavior prenatal magnetic-field exposure rats magnetism activity

WITH GROWTH of the space program, the number of experiments concerned with the effects of electromagnetic fields upon physiology and behavior has increased substantially. However, as noted in two recent review articles by Busby (1967) and Frey (1965), the vast majority of these studies was concerned with high intensity (10^3–10^5 gauss), static magnetic fields or high frequency (10^4–10^{10} Hz), electromagnetic fields. Few experimenters have examined the possible effects of low intensity (10^{-2}–10^1 gauss), low frequency (10^{-2}–10^4 Hz) fields upon behavior.

In nature, this range of frequencies and intensities is occupied by electromagnetic fields that include atmospherics, lower frequency waves, and geomagnetic pulsations. Reiter, as reported by Tromp (1963, p. 674–675), noted that days with high atmospherics counts were significantly correlated with increased reaction times in human subjects. Friedman, Becker, and Bachman (1967) also found increased reaction times in human subjects placed in a 5 to 11 gauss electromagnetic field created by a Helmholtz coil modulated at 0.2 Hz.

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Since short-term exposure to atmospherics and lower frequency electromegnetic fields produces immediate changes in simple reaction time, more permanent and serious behavioral consequences might be produced by prolonged exposure to these fields. To investigate these effects, it was decided to observe the behavior of rats that had been prenatally exposed to a 0.5 Hz, rotating magnetic field that varied from 3 to 30 gauss, in different parts of the experimental area. Prenatal exposure was considered optimal, since during this time the central nervous system and other organs are forming rapidly. Susceptibility to external factors is presumed to be especially great during this period.

Since in an initial study (Experiment 1) behavioral changes occurred, it was decided to replicate the study (Experiment 2) using controls that would minimize possible experimenter bias.

METHOD

SUBJECTS

EXPERIMENT 1. Twenty-three 3- to 7-month-old primiparous and multiparous Wistar strain female

rats obtained from Budd-Mountain Rodent Farm were used as breeders. On days that spermatozoa were found in the vaginal smears, 16 females were exposed to a rotating magnetic field, whereas the remaining 11 pregnant females were used as controls. Here the females remained for the whole period of gestation. Three of the litters that had been exposed prenatally to the magnetic field were fostered by other (control) females. Each fostered litter was composed of pups from 4 magnetic field-exposed litters. Three control litters spent their gestation in the apparatus after the magnets had been removed.

Sixty-four male and 53 female rats from litters prenatally exposed to a rotating magnetic field, and 47 male and 36 female rats prenatally exposed to control conditions were used as subjects in Experiment 1.

EXPERIMENT 2. Three pregnant primiparous females were exposed to the magnetic field, while 3 females were used as controls. The breeding conditions were the same as in Experiment 1.

Nine male and 10 female rats exposed prenatally to the field, and 14 male and 6 female rats prenatally exposed to control conditions were used as subjects in Experiment 2.

APPARATUS

ROTATING MAGNETIC FIELD APPARATUS. The magnetic field used in the present experiments was created by 2 permament horseshoe magnets, with a rating of 2100 gauss between the poles. The magnets were placed 30 cm apart, parallel to the ground, and were rotated in opposite directions around their major axes at 30 RPMs by an electric motor. The field induced between the magnets is called a Rotating Magnetic Field (RMF). The characteristics of the RMF were:

1. The intensity (as measured by a Rawson-Lush Gauss-meter) changed continuously from an average 15 gauss in the center half of the cage in which the pregnant females were housed, to a maximum 30 gauss nearest the magnets, and a minimum 3 gauss at the far ends of the cage. At any given point, the vector B field changed continuously from a maximum intensity north polarity, to zero, to a maximum intensity south polarity, to zero, etc.

2. The direction changed continuously 360° every 2 sec. (A hand compass placed between the rotating magnets rotated 0° to 360° in 2 sec.)

3. The poles of the magnets were parallel to the earth's surface and aligned in a northwest-southeast direction.

OPEN-FIELD APPARATUS. The wooden floor of a 63.5×63.5 cm open field was covered with white oil cloth marked into 25 squares (12.7×12.7 cm). The 33-cm high walls were also covered with white oil cloth. Illumination was furnished by a 20-w fluorescent lamp placed 65 cm above the surface of the field.

PROCEDURE

BREEDING AND HOUSING OF PREGNANT FEMALES. Breeding took place over a 12-month period. Each pregnant female was randomly placed into 1 of 2 plastic exposure cages ($27 \times 50 \times 30$ cm). The cages were covered with wire tops and on all 4 sides with cardboard, so that light entered only through the top. The number of females per cage varied from 2 to 5 during different breeding periods, but the number of females in the 2 cages at any one time did not differ by more than 1 animal.

One cage was placed between the magnets (RMF). Since the motor secured to a plywood base produced some vibration, the cage was placed on a platform 1.3 cm above and independent of the base. The control cage, except for the single instance noted in the subject section, was placed 200 cm from the nearest magnet. Although a Rawson-Lush Gaussmeter showed no deviation at this distance, a small, hand compass indicated a continuous 1 to 5° change in declination. The noise level measured 45 ± 2 db on the A scale of a General Radio Company Sound Level Meter (Type 155-a) in the RMF-exposed cage and 43 ± 2 db in the control cage.

Sanicel was used as absorbent material in the cages and was removed once every 6 to 7 days, to minimize handling of females. During cleaning, the females exposed to the RMF were out of the field for about 3 min. Illumination was constant, and was furnished by a 20-w fluorescent lamp 45 cm above the cage. Temperature averaged 25 ± 2°C. The relative humidity was not controlled and ranged from 20 to 90%. Other physical parameters were not recorded. Animals received Purina food and water ad libitum.

HOUSING OF YOUNG ANIMALS. After each female had given birth, the number of pups was recorded, and the pups and mother were placed in a $20 \times 24 \times 16$ cm wire cage with a screen mesh floor covered with 50 g of shredded paper. The litter size used in this study ranged from 5 to 8 pups. Larger litters were cut to 8 pups.

Each cage of mother and pups was removed from the experiment room and placed in the Department's rat colony room, which was programmed on a 12-hr, light-dark cycle. Background noise averaged about 50 db, with sporadic bursts up to 80 db. Temperature varied from 20 to 27°C. The relative humidity was not controlled and ranged from 30 to 90%. Mothers received food and water ad libitum.

OPEN FIELD. When a litter was 21 days of age, each

pup was removed for the first time from its mother (weaned), placed in a plastic carrying cage, and taken to the room where the open field was kept. This took 30 sec. The number of squares traversed and fecal boluses deposited in 2 min was recorded. At the end of the test, the animal was removed from the field and ear-punched. After the field was sponged over with 0.4% acetic acid (vinegar), the pup was placed again in the carrying cage and returned to a $43 \times 24 \times 18$ cm wire cage that housed pups of the same litter. Each animal was tested in the open field on 5 consecutive days (Experiment 1) or 3 consecutive days (Experiment 2). The median number of squares traversed in the 5 or 3 days was used as the rat's index of ambulatory activity. In Experiment 2, animals were tested by individuals who did not know whether a subject had been exposed to the RMF or to control conditions.

RESULTS

EXPERIMENT 1

The mean (M) and standard deviations (SD) of the median number of squares traversed over the 5-day test period by pups that had been exposed continuously to the RMF during prenatal development and their controls are presented in Table 1. RMF-exposed animals averaged 17.0 squares, whereas controls averaged 28.3 squares. The difference by analysis of variance was significant beyond the .001 level ($F=18.87$) (Table 2). The significant interaction was due to a significant difference between RMF-exposed males and RMF-exposed females. RMF-exposed males averaged 13.3 squares; RMF-exposed females, 21.8 squares ($p<.05$). Control males and females averaged 29.3 and 26.8 squares, respectively. This difference was not significant.

In Table 3, the means and SDs of the median number of fecal boluses deposited by RMF-exposed and control pups during the test period are presented. RMF-exposed pups averaged 1.1 boluses; control pups, 0.4 boluses. This difference was significant by analysis of variance at beyond the .001 level ($F=12.34$) (Table 4).

TABLE 1. *Means (M) and Standard Deviations (SD) of the Median Number (N) of Squares Traversed by Pups in Magnetic and Control Conditions*

Condition	Measure	Experiment 1		Experiment 2	
		Male	Female	Male	Female
Magnetic	N	64	53	9	10
	M	13.3	21.8	11.6	16.2
	SD	15.1	18.4	15.6	13.3
Control	N	47	36	14	6
	M	29.3	28.6	24.6	28.2
	SD	15.2	17.6	14.0	6.8

TABLE 2. *Analysis of Variance of the Median Number of Squares Traversed by Pups in Magnetic and Control Conditions*

Source	Experiment 1			Experiment 2		
	df	*MS*	*F*	*df*	*MS*	*F*
Treatment	1	5278.6	18.87[a]	1	1391.7	6.95[b]
Sex	1	431.1	1.54	1	149.7	<1
T x S	1	1451.7	5.17[a]	1	2.7	<1
Within	296	279.8	—	35	200.2	—

[a] $p < .05$.
[b] $p < .01$.
[c] $p < .001$.

Pups that had been exposed prenatally to the RMF but nursed by control mothers averaged 13.3 squares; their inter-uterine mates nursed by their own mothers averaged 13.2 squares. The difference was not significant. Also, control pups exposed prenatally to the RMF apparatus after the magnets had been removed did not differ significantly in their open-field activity from the animals in the usual control cage. RMF-exposed litters did not differ significantly from control litters in average number born, male/female ratio, or average weight (51.3 g and 45.8 g, respectively) at 21 days of age. The standard deviations for the latter measure were 4.4 g for the RMF-exposed rats and 5.0 g for the control rats.

EXPERIMENT 2

The means and SDs of the median number of squares traversed during the 3-day test period by pups exposed prenatally to the RMF and pups exposed prenatally to control conditions are also presented in Table 1. RMF-exposed pups averaged 14.1 squares, whereas control pups averaged 25.7 squares. The difference in mean square traversals between RMF-exposed and control animals was significant beyond the .01 level ($F=6.95$). A summary of the analysis of variance is presented in Table 2.

The means and SDs of the median number of fecal

TABLE 3. *Means (M) and Standard Deviations (SD) of the Median Number (N) of Fecal Boluses for Pups in Magnetic and Control Conditions*

Condition	Measure	Experiment 1		Experiment 2	
		Male	Female	Male	Female
Magnetic	N	64	53	9	10
	M	1.1	1.0	2.1	2.1
	SD	1.5	1.5	1.2	1.6
Control	N	47	36	14	6
	M	0.5	0.3	1.4	2.1
	SD	0.8	0.8	0.7	1.6

TABLE 4. *Analysis of Variance for the Median Number of Fecal Boluses for Pups in the Magnetic and Control Conditions*

Source	Experiment 1			Experiment 2		
	df	*MS*	*F*	*df*	*MS*	*F*
Treatment	1	20.6	12.34*	1	1.2	<1
Sex	1	<1	<1	1	1.2	<1
T x S	1	<1	<1		<1	<1
Within	296	1.7	—	35	58.9	—

* $p < .001$

boluses deposited in the open field are presented in Table 3. RMF-exposed animals averaged 2.1 boluses; control animals averaged 1.7 boluses. The difference in the number of fecal boluses between RMF-exposed and control animals was not significant. RMF-exposed litters did not differ significantly from control litters in average number born, male/female ratio, or average weight (55.1 g and 48.5 g, respectively) at 21 days of age. The standard deviations for the latter measure were 3.8 g and 6.6 g, respectively.

DISCUSSION

The results of these experiments have demonstrated that prenatal exposure to a 0.5-Hz rotating magnetic field (RMF) of intensities ranging from 3 to 30 gauss, can produce significant decrements in ambulatory activity and significant increases in defecation in an open-field situation. That this effect was not a function of differences in weight, number born, or postnatal density is also strongly indicated. Animals exposed to the magnetic field and animals used as controls did not differ significantly in the latter measures. It can also be concluded that the significant behavioral differences between RMF-exposed and control pups in the open field were independent of postnatal rearing factors by RMF-exposed mothers. The open-field behavior of RMF-exposed litters reared by control mothers did not differ significantly from their interuterine mates that remained with their own mothers. Hence, the differences between RMF-exposed and control animals can be attributed to some physiological change that occurred during prenatal development. This does not, however, eliminate the possibility that changes in the female's physiology during exposure could have affected fetal development.

The significant decrement in square traversals by RMF-exposed males when compared to RMF-exposed females, implied that males were more susceptible to the magnetic treatment. Although the reasons for this difference are not clear, other experiments have indicated that fetal exposure to a physical agent such as X irradiation may produce different effects in the two sexes (Werboff, Havlena, & Sikox, 1962).

The replication, with such a relatively small number of subjects, of the significant decrement in open-field behavior suggests that the observed effect was reliable. Even the magnitude of the differences was repeated. In Experiment 1, RMF-exposed rats averaged 17.0 squares, whereas the control rats averaged 28.3 squares. In Experiment 2, RMF-exposed subjects averaged 14.1 squares; control subjects, 25.7 squares. Since the animals in Experiment 2 were tested by two different experimenters who did not know which animals had been exposed to the RMF or control conditions, there is little possibility that the results of Experiment 1 were the effects of experimenter biasing. Further support of the magnetic effects is noted in the average number of squares traversed by RMF-exposed males as compared to RMF-exposed females and in the average differences in quantity of fecal boluses between RMF-exposed rats and the controls. Although these differences in the replication experiment were not statistically significant, they were in the same direction as in Experiment 1.

NOTES

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